REMARKS

Claims 1-13, 15-29 and 32-35 are pending in this application. Claim 1 has been amended to specify that tungsten cap layer that terminates the stack reduces roughness has a thickness of between 50 and 200 angstroms. Support for this amendment may be found in paragraph [0064]. Claim 9 has been amended to recited that depositing the tungsten nucleation layer comprises performing at least one pulsed cycle prior to flowing nitrogen, performing one or more pulsed cycles in the presence of nitrogen, and shutting off the nitrogen flow prior to the final pulsed cycle. Support for this amendment may be found in paragraph [0051]. Claim 15 has been amended to correct a claim dependency. No new matter has been added.

Rejections Under 35 U.S.C. § 112

Claim 15 was rejected under 35 U.S.C § 112, second paragraph for depending from a cancelled claim. Applicants have amended the claim to correct the dependency and overcome the rejection.

Rejections Under 35 U.S.C. § 103

Claims 1-8 were rejected as being unpatentable over Lee et al., U.S. Patent No. 5,956,609 ("Lee") in view of Klaus et al. "Atomically controlled growth of tungsten and tungsten nitride using sequential service reactions" ("Klaus") or Fang et al., U.S. Patent Publication No. 2003-0104126 ("Fang"). Claims 1-8 were also rejected as being unpatentable over Chang et al. U.S. Patent No. 5,028,565 ("Chang") in view of Klaus.

Claims 9-13 and 15 were rejected as being unpatentable over Lee in view of Klaus or Fang. Claims 9-13 were also rejected as being unpatentable over Chang in view of Klaus. Claims 16-18 were rejected as being unpatentable over any of these combinations in further combination with Berenbaum et al. U.S. Patent No. 6,066,366 ("Berenbaum").

Claims 19-29 and 32-35 were rejected as being unpatentable over Lee in view of Klaus or Fang. Claims 19-29 and 32-35 were also rejected as being unpatentable over Chang in view of Klaus.

Applicants respectfully submit that the claims as currently presented are patentable over the cited art for at least the reasons presented below:

Claims 1-8

Claims 1-8 are directed toward a tungsten deposition process wherein three distinct tungsten layers are deposited on a substrate: a tungsten nucleation layer, a tungsten bulk layer on the nucleation layer deposited by a CVD process; and a tungsten cap layer on the tungsten bulk layer deposited by a PNL deposition technique.

Claim 1 has been amended to specify that the cap layer has a thickness of between 50 and 200 angstroms. This is significant because, as explained in Applicants' specification, the tungsten cap layer serves to reduce the roughness of films. Film thickness is important for roughness because after certain amount of deposition, grains in a film grow relatively large and increase the roughness of the tungsten film (see, e.g., the discussion in paragraph 0061).

First, with regard to the rejection of claim 1 over the combination of Lee in view of Klaus or Fang, the Examiner relies on layer 34 of Lee to supply the cap layer. Lee shows three tungsten layers: nucleation layer 30, tungsten layer 32 having a thickness of 1200 angstroms and tungsten layer 34 having a thickness of 2000 angstroms.

Even if, for the sake of argument, the layer 34 of Lee reduces roughness as claimed, layer 34 has a thickness of 2000 angstroms. Thus, Applicants submit that claim 1 is patentable over the cited references.

With regard to the rejection over Klaus and Chang, Applicants note that previously, the Examiner rejected claim 1 over the combination of Klaus and Chang with Sukharev, stating that the combined teaching of Klaus and Chang "fails to disclose expressly (c) depositing a tungsten cap layer on the tungsten bulk layer using a pulsed nucleation layer (PNL) technique; and repeating (b) and (c) many times," but that Sukharev supplied this limitation. The Examiner has now removed this rejection in response to Applicants' arguments, but now contends that the claim is obvious over the combination of Klaus and Chang alone. Specifically, the Examiner contends that "when considering each deposited W layer for each cycle in formation of a bulk layer to be alternated bulk and cap layers, the claimed limitations" are met.

Applicants disagree with this last contention. As noted in previous responses, Chang teaches a CVD process which deposits a film after a vapor-phase reaction, while Klaus teaches a conventional ALD method of deposition tungsten using silane as a reducing agent. It is unclear in rejecting the claim, the Examiner means that the formation of the bulk layer would occur by CVD deposition (as in Chang) or by an ALD process (as in Klaus). Applicants request clarification, but submit that either way, "each deposited W layer for each cycle" may not be considered alternating bulk and cap layers. If the Examiner means that the formation of the bulk layer would occur using a CVD process as taught in Chang, Applicants note that Chang deposits the tungsten layer in one cycle (col. 3, line 36 – col. 4, line 14). There is no teaching or suggestion of using multiple CVD cycles. If the Examiner means that the formation of the bulk layer would occur using an ALD process as taught in Klaus, Applicants submit that an atomic scale tungsten layer deposited by a cycle of ALD as taught in Klaus may not be considered a "bulk layer." Thus, Applicants submit that "each deposited W layer for each cycle" may not be considered alternating bulk and cap layers.

Moreover there is no teaching or suggestion of depositing a capping layer having a thickness of between about 50 and 200 angstroms by PNL on a tungsten bulk layer, wherein the capping layer reduces roughness.

Claims 9-13 and 15-18

Claim 9 relates to a method of depositing tungsten that involves depositing a tungsten nucleation layer by PNL or ALD-type process and a bulk tungsten layer by CVD in the presence of nitrogen. To advance prosecution, Applicants have focused on a particular embodiment of the claims that involves performing one or more cycles of the PNL or ALD-type process without nitrogen, performing one or more pulsed cycles in the presence of nitrogen, and shutting off the nitrogen flow prior to the final pulsed cycle. As explained in paragraph 0051, in certain embodiments this nitrogen timing sequence prevents nitrogen from preventing initial tungsten deposition and/or poisoning any subsequent tungsten deposition processes.

None of the cited references, alone or in combination, teach or suggest involves depositing a tungsten nucleation layer by performing one or more cycles of alternating pulses of a tungsten precursor and a reducing agent, performing one or more the pulsed cycles in the presence of nitrogen, and shutting off the nitrogen flow prior to the final pulsed cycle.

For at least the reasons given above, claim 9 as amended is patentable over the cited art. Pending depending claims 10-13 and 15-18 are also patentable for at least these reasons.

Accordingly, Applicants request the Examiner withdraw these 35 U.S.C § 103(a) rejections.

Claims 19-29 and 32-35

Claim 19 has been amended to recite the steps of (a) forming an initial boron layer on the semiconductor substrate; (b) contacting the substrate with a tungsten-containing precursor that is reduced to form a tungsten layer on the semiconductor substrate; (c) contacting the semiconductor substrate with a silane; and (d) contacting the layer of silane with the tungsten-containing gas to thereby reduce the tungsten-containing gas to form another tungsten layer on the semiconductor substrate.

Claim 19 involves forming an initial layer of boron on the substrate surface, and using silane in a subsequent cycle. Claim 19 is supported by the parent application (issued as US Patent No. 6,635,965), the filing date of which predates the filing date of the Fang reference. None of the other cited references, either alone or in combination, teach or suggest forming an initial boron layer on the substrate and forming a silane layer in subsequent deposition cycles.

The Examiner asserts "that because the two reducing agents are well known to be equivalent, the use of one or both at different steps is not a matter of novelty but rather of convenience or design."

Applicants' disagree. Applicants' claimed invention recognizes that boron and silane are not equivalent. Rather, PNL tungsten film properties can be substantially altered by the choice and introduction sequence of process gases. As Applicants' specification and previous responses have emphasized, the use of boron in an initial step as well as the subsequent use of silane results in advantages that are not taught or suggested in any of the cited references. Using boron as an initial step provides benefits that are not realized when the substrate is initially exposed to other agents, including silane. For example, the initial boron layer reduces the sensitivity of the deposition process to variations in the incoming semiconductor wafers. Using silane for subsequent deposition processes instead of borane is advantageous in many embodiments because it can fully saturate any topography given sufficient dose times and improve step coverage. The claimed invention involves recognition of boron's value in an initial step as well as silane's value in a subsequent cycle.

At least because none of Klaus, Chang or Lee, either alone or in combination, suggest depositing an initial layer of boron, and then using silane in a subsequent step, Applicants submit that claim 19 is patentable over the cited art. Pending depending claims 20-29 and 32-35 are also patentable for at least these reasons. Accordingly, Applicants request the Examiner withdraw these 35 U.S.C § 103(a) rejections.

Conclusion:

In light of the foregoing amendments and remarks, Applicants respectfully submit that all pending claims are now in condition for allowance. Thus, Applicants respectfully request a Notice of Allowance from the Examiner. Should any unresolved issues remain, the Examiner is encouraged to contact the undersigned at the telephone number provided below. If the Commissioner determines that any fee is due that is not herewith submitted, such fee may be charged to deposit account No. 50-0388 (Order No. NOVLP033X1).

Respectfully submitted,
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